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Intracranial pressure monitoring complications at a major tertiary Hospital in Riyadh, Saudi Arabia

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ABSTRACT

Background: Intractable elevated intracranial pressure can lead to mortality or irreversible neurological brain damage. Thus, monitoring of intracranial pressure becomes a necessity in many traumatic and non-traumatic brain lesions. Potential risks and complications of monitoring include bleeding, bacterial infections, and injury due to probe misplacement. *Objective:* to identify and assess the complications related to intraparenchymal transducer intracranial pressure (ICP) monitoring at King Saud Medical City (KSMC) in Riyadh, KSA. *Design:* This is a retrospective cohort study. *Setting:* the neurosurgery department at King Saud Medical City

(KSMC). *Patients (Materials) and Methods:* This is a retrospective cohort study, which was performed from January 2016 until December 2018. Patients were recruited from the neurosurgery department at King Saud Medical City (KSMC). The patients were 14 years of age and older and used an intraparenchymal transducer ICP monitoring device during their admission. The collection sheet covered the following topics: socio-demographic variables, age at admission, gender, chronic diseases, indications, CT diagnosis and complications associated with intraparenchymal transducer ICP monitoring devices, GCS score at admission and discharge, and whether there Main Outcome Measures: complication rates due to ICP transducer monitoring. *Sample size:* 106 patients. Results: A total of 88.7% of patients did not have any complications. However, at the surgical site of intraparenchymal ICP monitoring insertion, 7.5% of patients developed wound infections, 1.9% of patients developed leakage, and 0.9% of patients developed both wound infections and leakage. *Conclusion:* The complication rates due to ICP transducer monitoring were low. Specifically, 88.7% of the patients did not have any complication, whereas 10.3% of the patients showed minor complications without serious consequences. These complications were treated immediately after they were diagnosed. *Limitations:* no limitation. *Conflict of interest:* Authors have no conflict of interest.

Keywords: ICP, monitoring devices, complications

1. INTRODUCTION

Intracranial pressure (ICP) is defined as the pressure within the intracranial cavity that protects the human brain (Kellie G, 1824).The volume of the intracranial cavity remains unchanged instable conditions. As a result, a constant ICP relies on the stability of the intracranial cavity contents, and the intracranial contents are the brain tissue, blood, and cerebrospinal fluid (CSF) (Brain TF, 2007; Bekar A et al., 2009).

Although the brain tissue is incompressible, a balance between the inflow and outflow of the fluid composition is essential to maintain a constant ICP. Specifically, a good balance is required between the inflow of arterial blood and the outflow of venous blood from the head, and as well as a balance between the rate of CSF production and drainage (Harary M et al., 2008). Therefore, an increase in the volume of any of the three components can result in elevated ICP. Furthermore, ICP can be increase by the addition of a fourth component such as a mass, intracranial hemorrhage, or cerebral edema that expands beyond the ability of the system to compensate. In addition, slight changes in ICP can occur under regular physiologic conditions including changes in posture, cardiovascular function, respiratory function, and brain activity (Bershad EM et al., 2008; Mounier R et al., 2015). The maintenance of ICP within its physiologic boundaries is essential to prevent brain injury (Imielin BL et al., 1998; Gardner PA et al., 2009). When ICP is sufficiently elevated, the pressure differential between the intracranial cavity and the spinal canal can cause the downward motion of brain tissue (i.e., herniation), which can compress vital brainstem structures and lead to severe neurological outcomes including death (Gardner PA et al., 2009; Fichtner J et al., 2010). Clinical ICP monitoring uses time-averaging to establish a baseline of ICP; an overnight measurement for at least 30 minutes is considered the "gold standard" for non-comatose patients (Hoefnagel D et al., 2008). Therefore, if alterations in ICP are sustained for more than 5 minutes, the result is considered clinically significant. The physiologic boundaries of mean ICP are 7–15 mm Hg in supine adults, 3–7 mm Hg in children, and 1.5–6 mm Hg in infants; however, mean ICP in pediatric populations may vary depending on age and is not well established (Arabi Y, 2005).

ICP monitoring device risk factors are associated with older patients, patients with long hospitalization, whether the patients were treated with steroids, and the primary illness of the patients (Wiegand C, and Richards P, 2007). In addition to the abovementioned factors, which affect changes in ICP, cerebrovascular autoregulation maintains a constant cerebral perfusion pressure (CPP) by changing cerebral arteriolar resistance. However, autoregulation works only in the CPP range of 50–150 mm Hg. When the CPP is below and above that range, hypoperfusion and cerebral edema may occur, respectively. Furthermore, autoregulatory capacity depends on the arterial pressure of carbon dioxide ($PaCO_2$) (Bekar A et al., 2009).

Hypercapnia causes dilation of cerebral vessels, which leads to an increase in cerebral blood flow (CBF). The dilation of cerebral vessels leads to an increase in CBF, which may cause hyper perfusion. However, hypocapnia causes vasoconstriction, which may cause ischemia (Bershad EM et al., 2008). To guide clinical management, early characterization of the components of ICP is essential. In their landmark 1927 paper, Adson and Lillie described the first instance of ICP monitoring using an external ventricular drainage (EVD)-based manometric system (Fakhry SM et al., 2004). Since then, indications for ICP monitoring have increased; currently, ICP monitoring is required for traumatic brain injury (TBI), subarachnoid hemorrhage (SAH), and hydrocephalus (Wiegand C, and Richards P, 2007).

A study was performed, which investigated the complications associated with intraparenchymal ICP monitoring using the Camino intracranial pressure device. A total of 328 patients were included in the study. It was observed that the duration of monitoring had no effect on the infection occurrence rate. Specifically, infections occurred only in 6 patients. Other observed complications included epidural hematoma (0.47%) and intraparenchymal hematoma (0.15%) (Bekar A et al., 2009). A large prospective study was performed at the Department of Surgery, Hospital of Santiago de Compostela, University of Santiago de Compostela, Spain. The study included 1000 patients. A total of 1071 Camino ICP monitors and 574 probe tips were examined. Using subsequent cultivation, it was determined that 8.5% of the patients were positive for bacterial growth. A control CT scan was performed in 92.2% of the patients. The incidence of hemorrhage was observed in 2.5% of the cases. Clinically significant bleeding was observed in 6 cases (0.66%) (4 intra-parenchymal and 2 epidural cases). Technical errors were reported in 4.5% of the cases and were frequently related to the fiber optic cable (Gelabert-González M et al., 2006).

A retrospective review study of 175 ICP monitors placed in 140 traumatic brain injury patients over a 3-year period showed a 10.3% infection rate. Factors associated with the development of ICP monitor-related infections included the duration of monitoring, requirement for serial monitors, and coincident infections at other sites (Abraham M and Singhal V, 2015). Another study was conducted at hepatic transfer centers in the USA on patients with brain edema and hepatic failure. During the study, the rates of complications associated with ICP monitoring were measured. It was established that the most commonly used devices at the abovementioned centers were epidural transducers. These devices demonstrated the lowest rate of complications (3.8%), while other devices (e.g., subdural bolts and parenchymal monitors) showed higher complication rates of 20% and 22% with the rate of fatal hemorrhage of 5% and 4%, respectively (Blei A et al., 1993).

A comparison between epidurally and subdurally placed pressure sensors showed lower measured ICP values in the subdural space; however, approximately equal ICP values were observed at above 20 mm Hg. In another study, which compared the lumbar CSF pressure with the epidural and subdural ICPs, higher pressure was consistently found for ICP in the epidural space; at higher-pressure intervals, the difference between the lumbar and epidural values was higher. It was concluded that higher ICP in the epidural space was due to physiologically different pressures in the two compartments (Weinstabl C et al., 1992).

2. METHODOLOGY

Patients gave their informed consent for participation in the research study.

Method and Study Design

A retrospective cohort study was performed from January 2016 until December 2018. The subjects were recruited based on the medical records of the patients at the neurosurgery department at King Saud Medical City (KSMC). A total of 118 patients of 14 years of age and older who used intraparenchymal transducer ICP monitoring devices participated in the study. Due to missing data, 12 patients were excluded from the study.

Materials

The data collection sheet included the following topics: socio-demographic variables, age at admission, gender, chronic diseases, indications, CT diagnosis and complications associated with intraparenchymal transducer ICP monitoring devices, GCS score at admission and discharge, and whether there was mortality and its relation to complications.

Ethical Issues

The approval to conduct the study was obtained from the head of the institutional review board committee. The consent from the hospital's administration was pre-requisite regarding the files of the patients. All data were kept confidential with limited access by the study team. No names were included at any stage of this study.

Statistical Analysis

The encoded answers were entered into Microsoft Excel, and descriptive analysis was performed using the statistical package for social sciences (SPSS) v.24 program. The outcomes of the results were analyzed using the t-test, and the proportional and percentile data were analyzed using chi-square. The Pearson correlation was used to study relationships between numerical values. The minimal level of significance was set at P 0.05 Alpha.

3. RESULTS

Distribution of ICP Complications among the Subjects. Figure 1 shows the general complications associated with the insertion of ICP monitors. It is observed that 88.7% of the patients did not report any complication. However, at the surgical site, 7.5% of the patients had wound infections, 1.9% of the patients had leakage, and 0.9% of the patients developed wound infections and leakage.

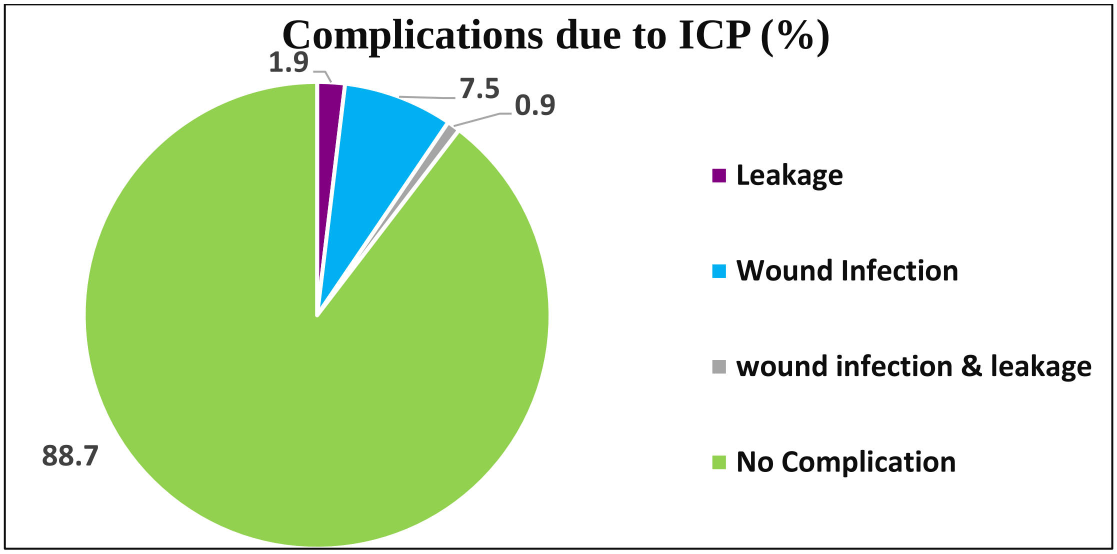

Figure 1 During the study, out of 106 patients, 89.6% were males (n=95), and 10.4% were females (n=11). There was a wide age range, and the mean age was 40.

Table 1 shows the GCS scores of the patients at admission. There were 61 (57.5%) patients with the GCS scores between 3 and 8. Similarly, 39 (36.8%) patient GCS scores were in the range between 9 and 12. The highest GCS scores of 13–15 were reported only in 6 (5.7%) patients.

At discharge, 69 (5.7%) patient GCS scores improved to the values between 13 and 15. In addition, 23 (21.7%) patient GCS scores improved to the values between 9 and 12. Out of 106 patients, the GCS scores of only 3 (2.8%) patients remained in the range between 3 and 8. However, 10 (9.4%) patients died, and 1 (0.9%) patient was in a vegetative state at the time of discharge.

By analyzing the complications in the patients with the GCS scores between 13 and 15, it was determined that 4 (3%) patients developed leakage, and 6 (4.5%) patients developed wound infections. Furthermore, it was observed that for the patients with the GCS scores between 9 and 12, 1 (0.7%) patient developed wound infections. Out of the patients who died (10 patients), only 2 (1.5%) patients developed leakage, and 2 (1.5%) patients developed leakage and wound infections. There was no association between the complications and death rate.

Table 1 Based on the Glasgow coma scale (GCS) score, GCS score on patients on admission and discharge and complication (N=106)

GCS Score and Condition	On admission	On discharge	Complications N (%)		
	Frequency Percent	Frequency Percent	Leakage	Wound Infection	Leakage & wound Infection
13-15	6(5.7%)	69(5.7%)	4 (3%)	6 (4.5%)	-
9-12	39(36.8%)	23(21.7%)	-	1 (0.7%)	-
3-8	61(57.5%)	3(2.8%)	-	-	-
Death	-	10(9.4%)	2 (1.5%)	-	2 (1.5%)

Vegetative state	-	1(0.9%)	-	-	1 (0.7%)
Total	106	106	6	7	3

Figure 2 shows the results of indication for ICP insertion and complications among the subjects. There was no significant difference between the traumatic subjects (i.e., intracerebral hematoma, subdural and epidural hematoma) and non-traumatic subjects (i.e., infarction, acute hydrocephalus, and brain space-occupying lesion). In addition, for the traumatic indication for insertion patients, at the surgical site, 5 (4.7%) patients developed wound infection, and 1 (0.9%) patient developed leakage and wound infections. For the non-traumatic indication patients, there were 2 (1.9%) patients with leakage and 3 (2.8%) patients with wound infections (P=0.216).

Table 2 shows the diagnoses of study participants based on CT. Out of 106 patients included in the study, 7(6.6%) patients were diagnosed with acute hydrocephalous, 71 (66.98%) patients were diagnosed with hematoma (including intracerebral, subdural, and epidural hematomas), 19 (17.9%) patients were diagnosed with infarction, and 9 (8.5%) patients were diagnosed with brain space-occupying lesion (including brain tumor and brain cyst).

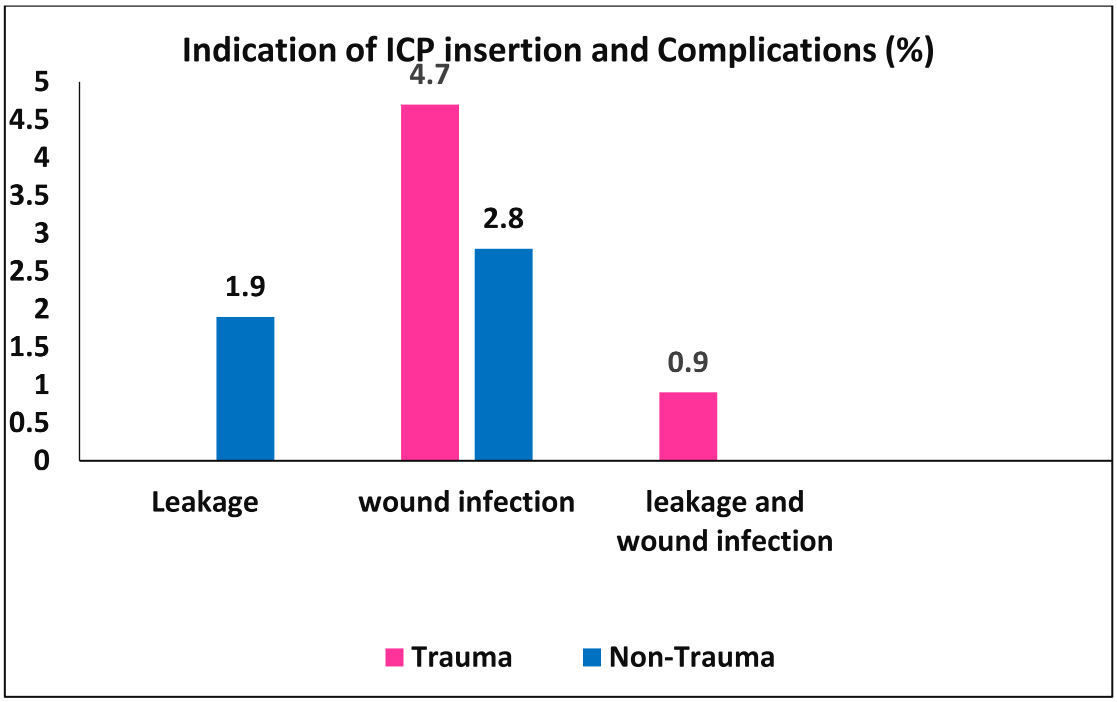

Figure 2 Indications of ICP Insertion and Complications among Subjects

Table 2 shows the study participants diagnosis based on CT. Among 106 patients included in the current study shows 7 (6.6%) patients were diagnosed as acute Hydrocephalous, 71 (66.98%) patient was diagnosed as hematoma included intracerebral hematoma, subdural and epidural hematoma, 19 (17.9%) patient was diagnosed as infarction, 9(8.5%) patients diagnosed as Brain space occupying lesion included Brain tumor and Brain cyst

Table 2 CT Diagnosis (N= 106)

CT Diagnosis	Number of patients	Percentage %
Acute Hydrocephalous	7	6.6
Hematoma	71	66.98
Infarction	19	17.9
Brain space occupying lesion	9	8.5
Total	106	100%

Figure 3 shows the associations between chronic diseases and complications due to ICP monitoring. The analysis indicates that there is no significant association between chronic diseases and complications due to ICP monitoring (P=0.79). In addition, the analysis indicates that there was 1 patient with a vascular disease (i.e., ischemic heart disease), 1 patient with hypertension (HTN) and diabetes mellitus (DM), and 1 patient with an endocrine disease (i.e., hypothyroidism) who developed wound infections at the surgical site. Out of 5 patients without chronic diseases who developed wound infections, 1 patient developed leakage, and 1 patient developed leakage with wound infections.

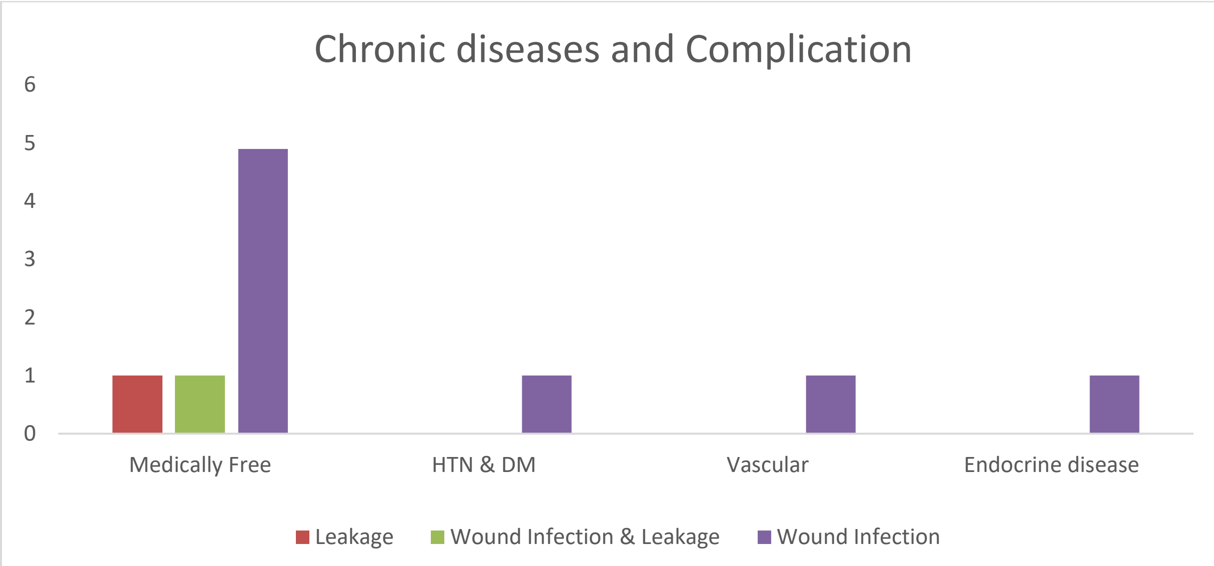

Figure 3 Chronic disease and Complications

4. DISCUSSION

ICP monitoring is used worldwide for traumatic and non-traumatic brain lesions. Our study aimed to assess the complications of using intraparenchymal transducer ICP monitoring devices at King Saud Medical City (KSMC). Intracranial monitors are not benign. Complications include hemorrhage, bacterial infections, and injury due to probe misplacement (Weinstabl C et al., 1992; Binz DD et al., 2009; Rosenberg JB et al., 2011). In a meta-analysis study (Binz DD et al., 2009; Rosenberg JB et al., 2011) of 1,790 catheter placements, the hemorrhage rates were reported to be 5.7%, with 61% of those deemed clinically significant. Bacterial infections are another critical issue. The rates for those are reported to be between 2.93% and 12%, even with strict sterile techniques employed during the placement of catheters. Incorrect placement of a catheter into undisturbed brain parenchyma may result in a direct injury to critical neurological functions. Regarding the types of complications in our study, out of 106 patients, 88.7% reported no complications, 7.5% developed wound infections, 1.9% developed leakage, and 0.9% developed wound infections and leakage. All complications were reported at the surgical site of the insertion of an intraparenchymal transducer ICP monitoring device.

Based on the Glasgow coma scale (GCS) score, at admission, 61 (57.5%) patients had the GCS scores between 3 and 8, 39 (36.8%) patients had the GCS scores between 9 and 12, and the maximum GCS scores between 13 and 15 were observed in 6 (5.7%) patients. In addition, at discharge, the GCS scores of 69 (5.7%) patients improved to the values between 13 and 15. The GCS scores of 23 (21.7%) patients improved to the values between 9 and 12. Out of 106 patients selected for this study, the GCS scores of only 3 (2.8%) patients remains between 3 and 8. However, there were 10 (9.4%) patients who died (there was no relation between the complications and death rate), and 1 (0.9%) patient was in a vegetative state at the time of discharge. (Chamoun RB et al., 2009) showed that patients with a GCS score of 3 had an overall survival rate of 50.8%. In addition, they found that 25.5% of the patients with bilateral reactive pupils and 27.6% with unilateral fixed and dilated pupils had a good outcome (Glasgow outcome scale score of 1 or 2) at six months.

By analyzing complications for the patients with the GCS scores between 13 and 15, it was determined that 4 (3%) patients developed leakage at the surgical site, 6 (4.5%) patients developed wound infections. Out of the patients with the GCS scores between 9 and 12, 1 (0.7%) patient developed wound infections. Out of the patients who died, only 2 (1.5%) patients developed leakage at the surgical site, and 2 (1.5%) patients developed leakage with wound infections; there were no associations between the complications and death rate.

In another study, out of 75 patients with the GCS scores of 8 and below with inserted ICP monitoring transducers, there were 9 (12%) complications. Out of those complications, there was a systemic infection in 3 cases (4%), epidural hematoma in 2 cases (2.7%), disconnection in 2 cases (2.7%), and contusion in 2 cases (2.7%) (Bekar A et al., 2009). Moreover, the Brain Trauma Foundation has published new guidelines for ICP monitoring in patients with severe traumatic brain injury (TBI) (Tariq A et al., 2017; So JS and Yun JH, 2017). Previous studies have found a higher survival rate in severe TBI patients with ICP monitoring. However, other studies have observed that the use of ICP monitoring in isolated severe TBI did not have any considerable survival benefits and was associated with the development of more than one complication, which increased the use of hospital resources (So JS and Yun JH, 2017). A retrospective review study of 175 ICP monitors placed in 140 traumatic brain injury patients over a 3-year period showed a 10.3% infection rate (Clark CW et al., 1989).

In our study, the traumatic indications for intraparenchymal transducer ICP monitoring insertions included intracerebral, subdural, and epidural hematomas, and non-traumatic conditions, which included infarction, acute hydrocephalus, and brain space-occupying lesion. Out of the patients with traumatic indications, at the surgical site, 5 (4.7%) patients devolved wound infections, and 1 (0.9%) patient devolved leakage and wound infections. Out of the patients with non-traumatic indications, 2 (1.9%) patients developed leakage, and 3 (2.8%) patients developed wound infections. There were no significant differences between the trauma and non-trauma patients (P=0.216).

Based on the observed chronic diseases and complications, we report that there was no significant association between chronic diseases and complications from intraparenchymal transducer ICP monitoring (P=0.79). In addition, the analysis indicates that there was 1 patient with a vascular disease (i.e., ischemic heart disease), 1 patient with hypertension (HTN) and diabetes mellitus (DM), and 1 patient with endocrine disorders (i.e., hypothyroidism) who developed wound infections at the surgical site. The wound infections among diabetic patients can be explained by permanently high blood glucose levels, which impair the function of white blood cells. Moreover, white blood cells are essential for the immune system. When white blood cells cannot function correctly, the body is less capable of fighting bacteria and closing wounds (Fakhry SM et al., 2004). ICP monitoring systems can be safely inserted in patients who either have or are at a risk of getting increased ICP. However, ICP monitoring complications vary between patients (Bekar A et al., 2009).

5. CONCLUSION

For the patients with inserted intraparenchymal transducer ICP monitoring devices, the rate of complications was low. Specifically, 88.7% of the patients did not develop any complications, whereas 10.3% of the patients developed minor complications, which were immediately treated after they were diagnosed.

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Conflicts of Interest: The authors declare no conflict of interest.

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